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# Maintaining and Improving the Los Alamos LANSCE Accelerator

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**Accelerator Operations and Technology**

2020 Accelerator Safety Workshop
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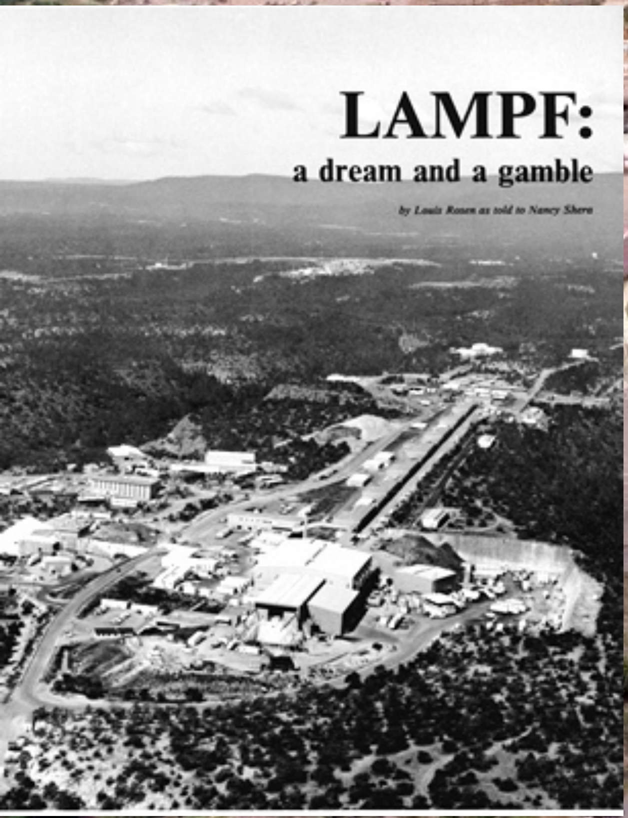
# LAMPF/LANSCE: 48 years



# The LANSCE LINAC provides flexible time-structured H+ / H− beams serving five experimental areas


- **Operations began in 1972**
  - Risk mitigation completed in 2015
- **800-MeV (1 MW) proton beam**
- **Highly capable/flexible facility**
  - 100 MeV to 800 MeV beam energy
  - 5 target stations
  - 3 neutron spallation targets
  - 16 beam lines
  - Time structure of beam allows for a large dynamic range of experiments
- **Dynamic proton radiography**
- **Neutron radiography**
- **Structural material properties**
- **Nuclear properties of materials**
- **Fundamental physics**
- **Isotope production**

# Overall the machine and systems have been great, but we are starting to suffer on the old age end of the bathtub curve.

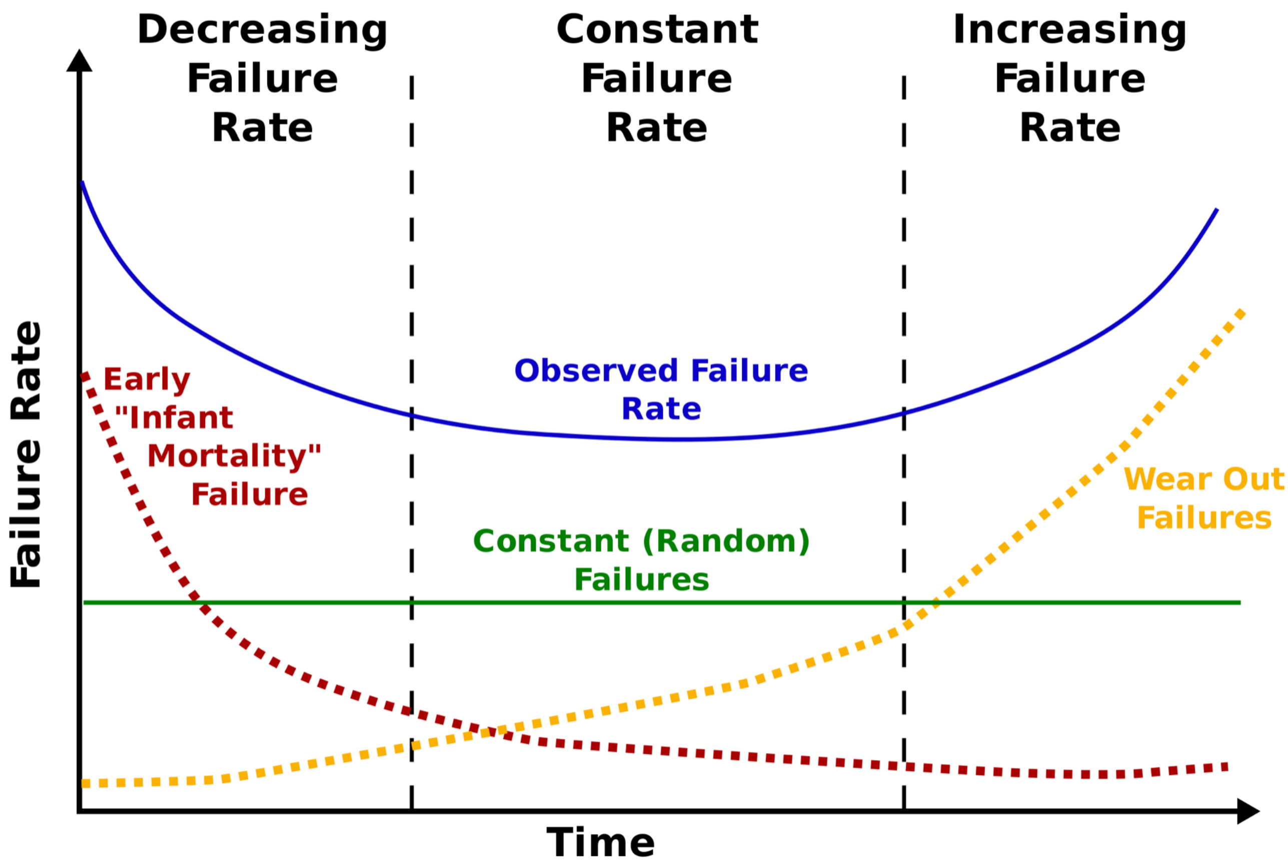
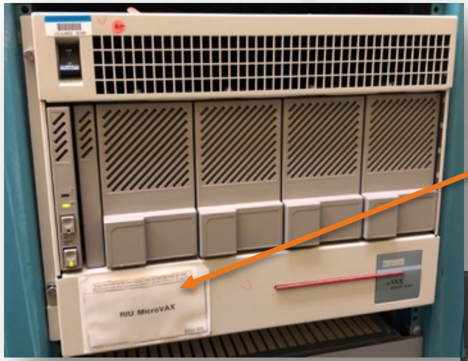


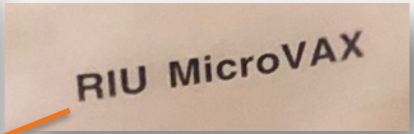

Chart obtained from Bathtub Curve – Wikipedia

# LANSCE Operations has been having some significant issues over the past few years due to aging infrastructure

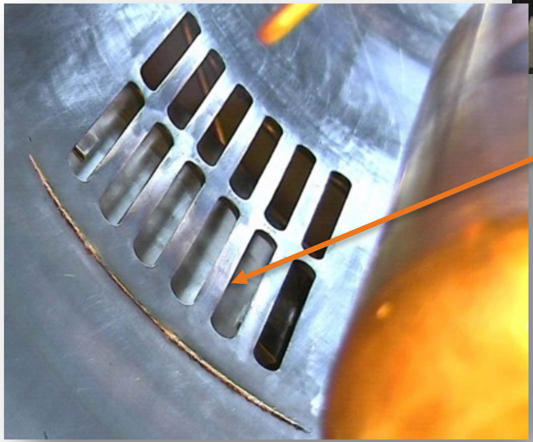
- 2017: Tuning issues
  - Human performance
  - Slow controls system, poor diagnostics and old software
- 2018: Proton Storage Ring (PSR) Septum magnet
  - Premature failure
    - Potentially due to previous year difficulties
  - Lack of completed spare
- 2018 (or well before) 2019
  - 2018 forced 60 Hz operations

    Significant impact on Weapons Neutron Research (WNR) program
  - Drift Tube Linac (DTL) Tank 3 Crack
  - Took a lot of time to understand, determine the cause, and to determine the best method of repair



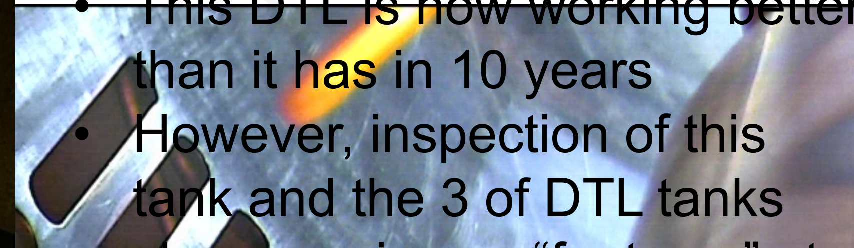



Installing the new Septum Magnet



DTL tank 3 crack before repair

# The “Crack” of 2019

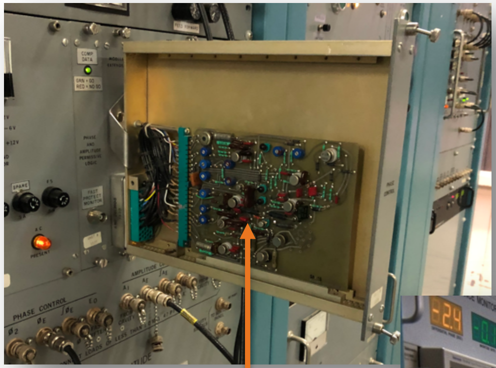
- This DTL is now working better than it has in 10 years
- However, inspection of this tank and the 3 of DTL tanks show worrisome “features” at weld joints

# We are still using very old technology, Cockcroft-Walton Accelerators, that pose significant operational risk

- We currently have two in operation, one for protons and the other for $H^-$ (We once had 3. One for a polarized source
- We do not have a complete set of spares! And the companies that built many of these components no longer exists
- These are true work horses, and very capable, but have been replaced around the world by more modern and more capable RFQ-based injector systems
- We could choose to
  - Invest in RFQ injectors
  - Spend money to buy the necessary spares
  - Do both to burn down risk

# CW/DTL vulnerabilities aside, we continue to push forward to improve overall performance and reliability

- LLRF
  - Old analog cards are being replaced with modern digital LLRF system
  - Expect recapitalization money in 2022, so until then we will do what we can with programmatic funds.



A dLLRF system on the 201 MHz system with a happy user

'70s analog LLRF Prevalent throughout the CCL linac

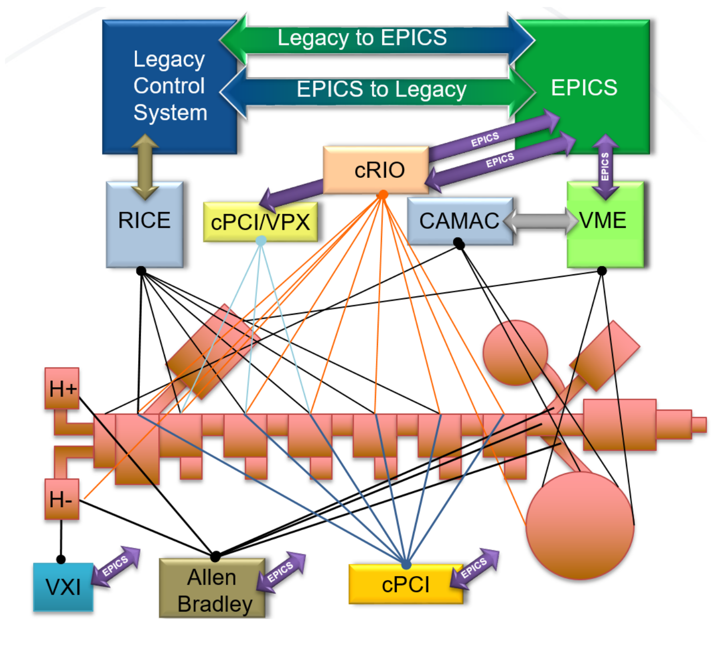
- Controls and instrumentation
  - Modern architecture and updated equipment
  - We have $7.4M in recapitalization funds to make significant progress on this over FY 20 and FY 21


The name dates itself

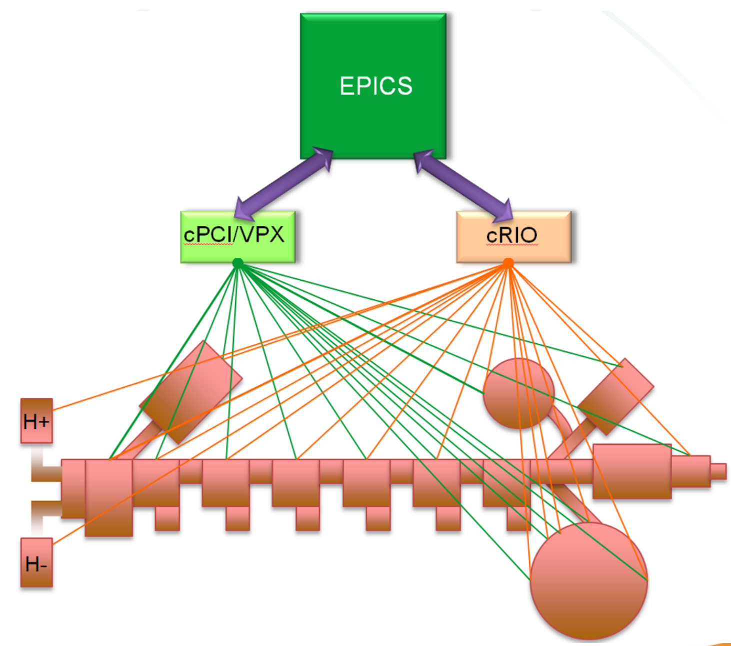
- Others in the works
  - 1L Target replacement (2021, funded)
  - CCL quad coils (2020-2022, partly funded)
  - Module 1 power system (2020, funded)
    - Completes all DTL RF power system upgrade

# But reality sometimes forces one to do things a little at a time and you get into “hybrid space”.

- Example: The LANSCE Control system
  - We currently need to maintain a hybrid mixture of old and new
  - This has HUGE consequences and is fraught with unintended consequences




Today




Future

# One must also be careful to worry about the aging infrastructure that supports the accelerator systems

# So how does one proceed?

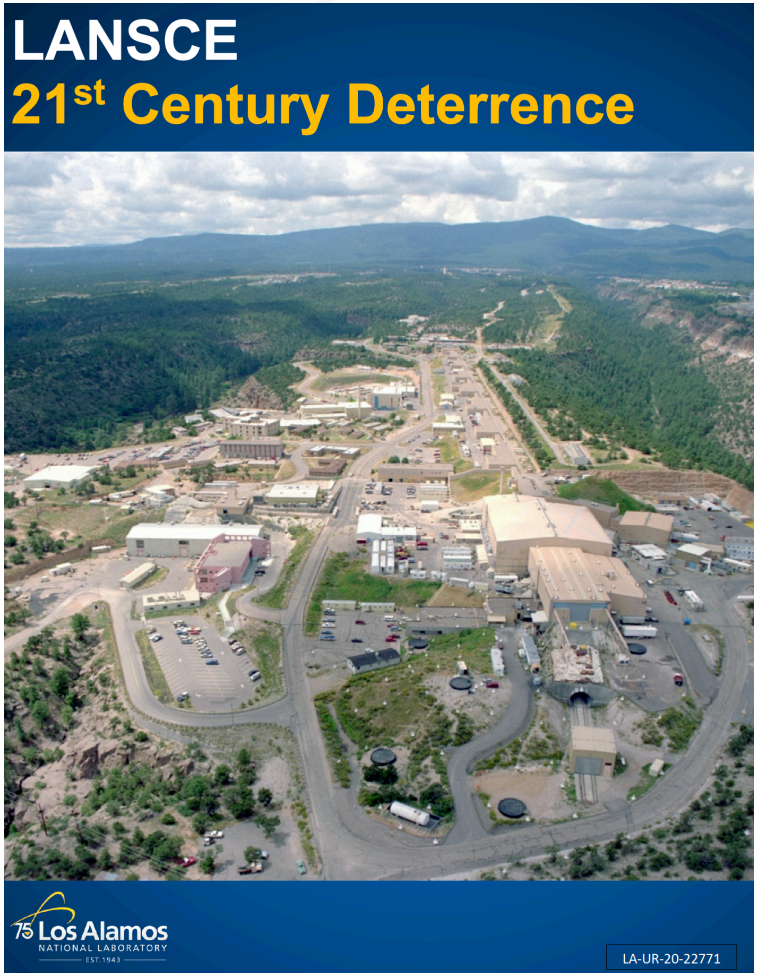
- Look at your needs and future plans
  - Do you
    - Maintain as is
    - Grow current capability
    - Transition to something new
  - all while correcting the age related issues
- Determine your risks
  - Categorize them (High, Medium, Low)
    - Likelihood
    - Impact
    - Cost
    - Time and Effort
- Set a path, a plan, and execute
  - Or at least try

| Likelihood ↑ / Impact → | Negligible | Minor | Moderate | Significant | Severe |
|---|---|---|---|---|---|
| Very Likely | Low Med | Medium | Med Hi | High | High |
| Likely | Low | Low Med | Medium | Med Hi | High |
| Possible | Low | Low Med | Medium | Med Hi | Med Hi |
| Unlikely | Low | Low Med | Low Med | Medium | Med Hi |
| Very Unlikely | Low | Low | Low Med | Medium | Medium |

# In addition, we are working to implement maintenance analytics and focus on a process-based system

- What is maintenance analytics?
  - It is taking all the available operational and performance data along with historical facts, compiling it all and using this information in a proactive fashion to analyze and determine maintenance needs in a predictive or prognostic fashion.
  - We will also use this information to optimize delivery metrics based on available resources
    - Time
    - People
    - Money
- Move from expert-based system to a process-based system
  - Need to develop long-term robustness.
    - This is not possible with an expert-based system

# A document highlighting the path to LANSCE 2050 was recently published




- Most immediate concern
  - Aging Cockcroft-Walton and Drift-tube linac (DTL) system
    - Failed weld in DTL during 2019 run resulted in many weeks of lost user time
- LANSCE Front-End Upgrade (LFEU)
  - Replace Cockcroft-Walton and Drift-Tube Linac system with an RF Quadrupole-based system
  - Improvements (From document)
    - Higher peak and integrated current capabilities
    - Lower emittance
    - To experimental areas
      - Improved resolution for pRad
      - Increased throughput at the Lujan center
      - Increased capability at WNR
      - Increased production capability at IPF

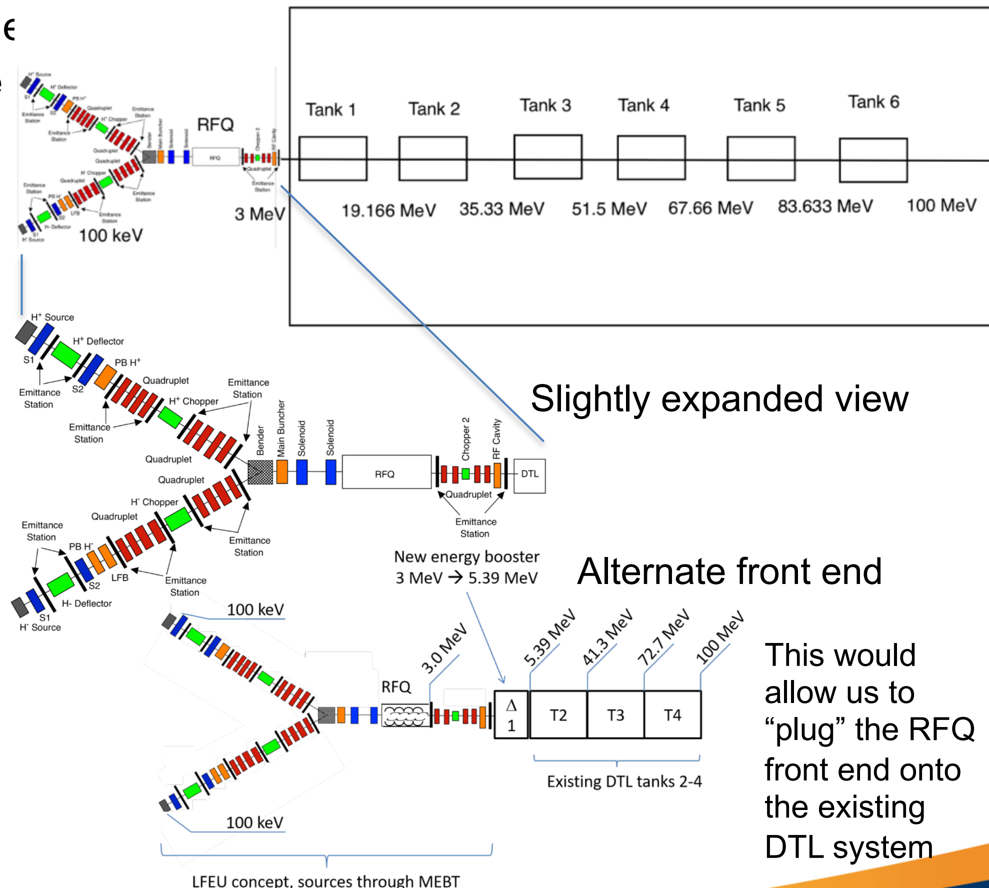
# A pre-conceptual design report for the LFEU has recently been generated

- Primary Purpose
  - Provide a proof-of-concept docume
  - Generate initial cost and schedule

Key performance Parameters

| v1.11 – 2019-12-10 | | | Value | | |
|---|---|---|---|---|---|
| Parameter | Symbol | Unit | Threshold | Objective | Ultimate |
| | | | | | |
| Beam delivery | | | | | |
| Kinetic energy | $E_k$ | MeV | 100 | 100 - 211 | 100 - 211 |
| Micropulse current[‡] | $I_{\mu p}$ | mA | 16.5 | 35 | 50 |
| Macropulse duration | $\tau_{mp}$ | μs | 625 | 850 | 1000 |
| Rep rate | $f_{rep}$ | Hz | 120 | 120 | 240 |
| Capture fraction | $\eta_{inj}$ | - | 0.8 | 0.9 | 0.9 |
| Min. avg. current | $\langle I \rangle$ | mA | 0.75 | 3[1] | 6 |
| Norm. emittance | $\varepsilon_{rms,n}$ | π mm mr | 0.35 | 0.30 | 0.25 |
| Fractional momentum Spread | $\Delta p/p$ | - | 0.003 | 0.003 | 0.003 |
| Bunch length | $l_b$ | mm | 5 | 5 | 5 |
| Source service Recovery | | hours | 24 | 6 | <1 |
| | | | | | |
| Beam Gating | | | | | |
| Pattern | | | Arbitrary | | |
| Minimum flattop | | # bunches | 5 | 1 | 1 |
| Maximum flattop | | μs | $\tau_{mp}$ | | |
| Contrast ratio | | | $7.7\cdot10^8$:1 | $7.7\cdot10^8$:1 | $1.5\cdot10^9$:1 |
| Rise/fall time | | ns | 10 | 2 | 2 |
| Prebuncher $I_{\mu p}$ mult. | | | 2.5 | 2.5 | 5 |
| | | | | | |
| Source | | | | | |
| Maintenance interval | | Weeks | 5 | 8 | 16 |
| Downtime per service | | Days | 3 | 2 | 1 |
| Minor fault recovery | | Sec | 180 | 120 | < 60 |
| Minor fault rate | | #/day | 10 | 3 | <1 |

Overview of Design Scope




Slightly expanded view

Alternate front end

This would allow us to “plug” the RFQ front end onto the existing DTL system

# Some summary thoughts

- The metaphorical question
  - Do you continue to maintain the old car or do you go out and buy a new one?
    - We think our “old car”, the LANSCE accelerator system, still has quite a bit of life in it.
    - However, we might one day find ourselves with Abraham Lincoln’s* ax.

Legend: When Lincoln was once asked about his ax he replied,

> *“I’ve had this same ax my whole life. I’ve only had to replace the handle 3 times and the head twice.”*

Painting of Abraham Lincoln by Norman Rockwell

*Abraham Lincoln was the 16th president of the United States and is best known for seeing the US through the civil war and abolishing slavery in the US.

# Questions?